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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

MINERAL WOOL

BY

J. R. THOENEN

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MINERAL WOOL[1]

By J. R. Thoenen[2]

DESCRIPTION AND USES

Mineral wool is a substance composed of very fine, interlaced threads chiefly of calcium silicate or glass-like materials similar in appearance to wool or cotton. Because of the high percentage of air space for a given volume of mineral wool, it is used mainly for insulating purposes.

Insulation has two principal functions; retention (or exclusion) of heat, and sound control. Mineral wool finds a considerable market for use in high-temperature insulation as a cover for pipe, annealing and baking ovens, and metallurgical and chemical furnaces, and in low-temperature insulation as stove and fireless cooker linings. Processed in a different manner it makes an efficient insulator for such uses as filling for house walls and floors, refrigerator lining, and covering for house and underground pipe lines. Used in interior walls and like places, it is an efficient sound deadener as well. Because of it's acid-proof properties it is also used as packing for acid carboys and as a filter medium for acids and corrosive liquids and gases.

Mineral wool may be divided into two classes - rock wool and slag wool. The differentiation is based on the nature of the raw materials used in its manufacture. Rock wool is made from a natural siliceous limestone (more properly classified, perhaps, as a calcareous shale) found in northern Indiana[3] or from an artificial mixture of silica and limestone. Slag wool is made from iron blast-furnace slags with or without the addition of limestone to temper the charge.

SOURCES OF INFORMATION

Numerous inquiries received by the Bureau of Mines as to the nature and use of mineral wool prompted a study of the material, and in the absence of other than very meager published literature on the subject a field trip was made to the producing plants. This paper presents the data collected during that field study in December, 1928, and February, 1929, together with information gathered by the author during previous personal contact with the industry.

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[1] - The Bureau of Mines will welcome reprinting of this article, but requests that the following footnote acknowledgment be used: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

[2] - Mining engineer, U. S. Bureau of Mines.

[3] - Cummings, E. R., and Shrock, R. R., The Geology of the Silurian Rocks of Northern Indiana. Dept. of Conservation, Division of Geology, Indianapolis, Ind., Publication No. 75, 1928.

HISTORY OF THE INDUSTRY

Little data concerning the history of the industry are obtainable, although Lang[4] states that mineral wool has been made for over 50 years.

Some years ago a slag-wool plant was operated near Pasadena, Calif., but the author is informed this plant is not now in existence. Also, it is said that there is a plant in Tennessee, but no information is available concerning it.

Rock wool was probably first made at Alexandria, Ind., in 1897 by Mr. C. C. Hall, Manager of the Banner Rock Products Co. Mr. Hall at that time was employed by St. Louis interests as a chemical engineer and manager of a steel plant that was designed and erected under his supervision at Alexandria, Ind. In the search for suitable rock for fluxing purposes in this plant, the peculiar composition of a local deposit was ascertained.

Mr. Hall resigned his position and began experimenting with this rock first to see if it would melt and then to see if it would make a fiber. The abundance of natural gas suggested its use as a fuel, and it was so employed. Mr. Hall's first production of wool was on the premises of the steel plant, but as this plant was absorbed by one of the steel trusts then forming, Mr. Hall had to move such equipment as he had assembled. At this time he formed with some Alexandria friends a corporation known as the Crystal Chemical Co. This second plant was operated until about 1901 when it was sold to a St. Louis company which ultimately was succeeded by the present General Insulating & Manufacturing Co., with headquarters in St. Louis.[5] In 1906 Mr. Hall withdrew from this company and formed the Banner Rock Products Co., which was incorporated in September, 1906, and has operated continuously since January, 1907.

The Union Fibre Co., Inc., for several years operated a small plant at Yorktown, Ind., but they have recently abandoned this site and moved to Wabash, Ind., where they have built a modern plant.

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4 - Lang, Herbert, Designing and Operating a Slag Wool Plant. Chem. and Met. Eng., Aug. 27, 1923, pp. 365-367.

5 - Thoenen, J. R., Mineral Wool and Cement from a Silicified Lime Rock. Rock Products, Feb. 21, 1925, p. 39.

Mineral wool is at present manufactured by the following companies:

Companies employed in the manufacture of mineral wools

Company	Plant location	Number of furnaces	Kind of wool
Banner Rock Products Co.	Alexandria, Ind.	10	Rock.
Johns-Manville Corporation	Waukegan, Ill.	1	Slag.
Johns-Manville Corporation	Manville, N. J.	1	Slag.
General Insulating & Mfg. Co.	Alexandria, Ind.	6	Rock.
Union Fibre Co., Inc. (Winona, Minn.)	Wabash, Ind.	2	Rock.
United States Mineral Wool Co.	Netcong, N. J.	3	Rock and slag.
Columbia Mineral Wool Co.	South Milwaukee, Wis.	2	Rock and slag.
Webber Cement Insulation Products Co.	East Chicago, Ind.	1	Slag.

The Banner Rock Products Co. has recently been purchased by the Johns-Manville Corporation, and the Columbia Mineral Wool Co. is subsidiary to the U. S. Mineral Wool Co. The plant of the Webber Cement Insulation Products Co. was not visited by the author, but it is understood that this plant operates on slag from a local smelter and its whole wool product enters the market as an ingredient of insulating cements.

MINING PRACTICE

For the manufacture of slag wool, the slag is loaded from the dumps either by hand or by mechanical shovel and transported to the manufacturing plant. Some operators have located their wool plants adjacent to old abandoned dumps and do their own loading. Others buy their slag from the iron companies which then reclaim the slag from the dump and deliver it to the wool operator. Often the material is transported for several miles. So far no wool plant is known to utilize slag while still molten.

The natural Indiana wool rock, on the other hand, is mined from open quarries. Cummings and Shrock[6] give a detailed description of the geology and occurrence of this rock, and the author[7] has described the general quarry practice. The shallow depths and thin beds of the material favor the use of hammer or piston drills, but at least one company has opened a deposit of considerable thickness and plans to install churn drills.

Some of the deposits are soft enough to be mined without blasting. Elsewhere as much as 1 pound of explosive may be required per ton of rock broken.

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[6] - See footnote 3, p. 1.

[7] - See footnote 5, p. 2.

Overburden is stripped by hand or steam shovel. The broken stone is loaded by hand or shovel and conveyed to stock piles, where it is stored during the winter season to obviate mining except in summer.

MANUFACTURING PRACTICE

Handling Materials

Both rock and slag are melted in cupolas, very much like cast iron. To convey the raw materials to the tops of the cupolas various means are employed, among which may be mentioned bucket elevators, elevator and cars, and cranes.

Coke is the usual fuel employed and is charged in alternate layers with the slag or rock in the tops of the cupolas. The charge is proportioned at some plants by counting the shovels of each material; at others monorail buckets are used, and the charge is proportioned entirely by weight.

Cupola Practice

The cupola in almost universal use is of the vertical-cylinder water-jacketed steel type, roughly 7½ feet in diameter by 16 feet in height. Blowing tuyeres are placed about two feet above the bottom, and the molten material is drawn off near the bottom through a fire-clay lined opening. Air is introduced through the tuyeres by blower fans at low pressures. The bottom of the cupola is arranged with drop doors to facilitate cleaning. The water-jacketed cupolas are said to have a capacity of 1,000 pounds of wool per hour and are operated continuously six days per week when in production.

Brick cupolas of the same general dimensions have been used in the past and are at present used by one company. The brick units operate only part of the 24 hours, and repairs to the lining are made while the cupolas are idle.

In some instances the water-jackets are used to generate steam for power purposes and for wool blowing.

Blowing Wool

The molten material issues from the bottom of the cupolas in a small stream, the flow and temperature of which are carefully regulated. The slag as it falls is broken up by a steam jet (at 80 to 100 pounds pressure) into minute balls or shot , which while still in a molten condition are propelled rapidly through the air. In passing comet-wise through the air, fine threads of glass-like material form as tails to the shot and fall in a fluffy mass on the floor of the wool room.

The best form and shape for the steam-jet blower is a subject of considerable controversy among operators. The various operators advocate their own particular design and maintain more or less secrecy concerning its details.

Generally speaking they are all so arranged as to form the issuing steam into a trough which receives the falling slag.

Gathering Raw Wool

The wool blown into the wool rooms is gathered either by hand or on conveyor belts, for further processing.

Some operators arrange two wool rooms for each cupola, so that wool may be blown into one while being gathered by hand from the other. Others blow into one room and gather the wool while the cupola is down for repairs. More modern practice involves continuous blowing into a single wool room, the floor of which is formed by a moving conveyor belt which gathers the wool automatically as it falls, and passes it on for further processing.

FINISHED PRODUCTS

Loose wool is the sole product of several plants and finds a ready market wherever a loose insulating material is required. Mineral wool is also used in loose form as a filter medium for acids and corrosive gases, as well as for packing around acid carboys for shipment.

Loose wool is run through machines termed "granulators," the function of which is to break the shot from the fine threads and remove it. This treatment results in a short-fiber, shot-free wool which is used for mixing with other materials in the manufacture of insulating cements. This material is also used extensively as house insulation. The granulated wool is blown by low air pressure into the spaces between the studding and joists of buildings already constructed and forms a very effective heat and sound insulator.

In addition to the method of using granulated wool for house insulation as already noted, raw wool is placed between wire netting such as window screening, chicken wire, or chicken wire and metal lath. These "blankets" are made in various sizes and thicknesses to suit consumers and for house insulation are placed directly on the studdings or between them. Where metal lath is used on one side, the lath is plastered in the usual manner. Similar products are made for refrigerator and cold-room linings. Blankets are also used for boiler and oven coverings, and are in turn covered by insulating cement. Covering for outdoor tanks in which liquids must be kept above freezing is a similar use for this class of fabrication.

Used in blankets or as loose wool the material is said to be of great benefit in controlling the acoustic properties of buildings, and in rendering noiseless small machinery units such as house refrigerator motors, etc.

Probably the greatest use for raw and granulated wool is in the manufacture of "rock cork" or "rock felt." Blocks of this material are made in various sizes and thicknesses for refrigerator lining. Raw or granulated wool, together with other ingredients and various binders, is mixed with water into a stiff mud and is placed on pallets and subjected to low pressure. These pallets are then run on racks into drying rooms and dried in a current of hot air.

This material is also molded into forms for pipe covering and is covered with cotton. Often it is reinforced with chicken wire.

High-temperature insulation is made from a mixture of refractory binders with the wool; the whole mixture is compressed into blocks or brick. Such material is used for covering glass and metallurgical furnaces, annealing and enameling ovens, and for pipe covering.

Various grades of raw wool are sold, depending on the consumer's specifications. No standards have as yet been set up. Some consumers demand that the wool shall be oiled, whereas others require that it be dry. Prices depend on competition with similar insulating materials and even for similar grades are likely to vary in different contracts.

The following prices are indicative only:

Raw wool - $20 to $25 per ton.
Granulated wool - up to $40 per ton.
"Flex felt" and "blankets" - 8-10 cents per board foot.
Block - 15 cents per board foot.
Cork board - 7 cents per board foot.
Pipe covering - Standard 85 per cent magnesia list, less 50 per cent.
Brick - $100 per M.

DESCRIPTION OF PLANTS

There are many elements in the manufacture of mineral wool which must be classed as secret trade practices. Therefore the following description of plants must be confined to more or less general information to avoid disclosing private practices.

Johns-Manville Corporation

Banner Rock Products Plant, Alexandria, Ind.

The Banner Rock Products Co. operates a large open quarry of wool rock which is covered by 3 to 5 feet of clay and loam overburden. Stripping is done by steam shovel and drag line. The wool rock attains a maximum thickness of 15 to 20 feet and tapers in all directions.

The rock is drilled with steam piston and air hammer drills, blasted with 40 per cent gelatin dynamite, and loaded into small quarry cars by hand and steam shovel. Loaded cars are trammed to the foot of an incline and hoisted to a storage pile adjacent to the kilns or cupolas.

The manufacturing plant consists of the original four-cupola installation and a new modern six-cupola plant.

In the old part of the plant the cupolas are charged by hand, but in the new plant raw materials are brought to the charging floor by an overhead traveling crane which deposits the rock and coke in alternate bins near the tops of the cupolas. A traveling bucket operating on a monorail is loaded by hand from the various bins, weighed, and dumped into the hoppers over the cupolas.

The cupolas are all of the standard, vertical, steel-cylinder, water-jacketed type. Draft is furnished by blower-type fans. Owing to the hardness of the local water, it must be treated before circulation through the jackets.

In the old plant the wool is blown into alternate wool rooms from each cupola, but the rooms in the new plant are fitted with sloping sides and a narrow conveyor belt at the bottom. This insures automatic and continuous collection of wool.

Arrangements are such that the finished wool can be sent on conveyors direct to fitting tables for fabrication into blankets or to granulators and thence by elevators to the mixing tanks for the preparation of rock cork.

The whole new plant is designed to utilize all possible automatic transportation devices and thus insure constant and continuous operation with a minimum of labor.

The plant employs approximately 300 men, and has a potential capacity of 10,000 pounds of wool per hour.

Waukegan, Ill.

The equipment of the plant at Waukegan consists of one standard water-jacketed cupola and operates on slag obtained from an iron blast furnace at Mayville, Wisconsin. Composition of the slag was given as:

	Per cent
SiO_2	38.0
Fe_2O_3.	1.0
Al_2O_3.	11.0
CaO	28.0
MgO	19.0
S	0.5 - 0.8

Occasionally the charge must be tempered with other raw materials to insure the correct chemical control. The cupola is charged by hand, and the blowing practice is standard. No fabrication is attempted except in the form of blankets.

Plant capacity is 1,000 pounds of wool per hour.

Manville, N. J.

The plant at Manville, N. J., also uses slag as a raw material. Although the plant was built as a production unit, it is now used primarily as a technical experimental plant.

The raw materials are charged into the single standard cupola from overhead bins and the wool is blown into a vertical-sided room in which the floor is a conveyor belt. A short conveyor belt takes the blown wool from the collecting conveyor for sacking.

No fabrication is attempted at this plant. Plant capacity is 1,000 pounds of wool per hour.

General Insulating & Mfg. Co., Alexandria, Ind.

The plant of the General Insulating & Manufacturing Co. at Alexandria, Ind., was described by the writer in the February 21, 1925, issure of Rock Products, and the reader is referred to that article for a detailed account of operation.

The plant operates on Indiana wool rock from nearby quarries. Six water-jacketed cupolas are used, and various products are fabricated. The plant has a potential capacity of roughly 6,000 pounds of wool per hour.

United States Mineral Wool Co.

Columbia Mineral Wool Co., South Milwaukee, Wis.

The Columbia Mineral Wool Co. at South Milwaukee, Wis., likewise uses slag from the Mayville Iron Co. as raw material, but both Mayville dolomite and red granite are added with the slag in the cupola charge to obtain the correct chemical control.

The wool is blown from one standard water-jacketed cupola, using a fan-type blower for cupola draft, into alternate wool rooms and collected by hand.

No wool is fabricated at this plant.

Capacity of plant is 1,000 pounds per hour.

Netcong, N. J.

The U. S. Mineral Wool Co. operates one brick cupola at Netcong, N. J., for 16 hours daily. During the idle 8 hours the cupola is entirely relined with a local clay and the wool is removed from the blowing room. A second brick cupola and also a standard water-jacketed cupola are available but were not operating at the time of the author's visit.

At this plant both rock and slag wool are made. The slag is obtained from abandoned dumps of the Replogle Steel Co. Raw calcite is added to the slag charge to control the proper mixture.

For making rock wool, silica rock and crystalline calcite are purchased from nearby sources. The fuel charge with these raw materials consists of a mixture of anthracite coal and coke. With the slag, coke is used alone.

The blowing operation is similar to that already described, and the wool is collected by hand from the blowing chamber.

No wool is fabricated.

The plant capacity is 1,000 pounds per hour for 16 hours daily with one cupola. Operating the three cupolas, the potential capacity would be tripled.

Union Fibre Co., Inc., Winona, Minn.

Wabash, Ind.

The Union Fibre Co., Inc., recently transferred its operation from Yorktown, Ind., to Wabash, Ind., where a modern plant has been erected.

The raw material used is the Indiana wool rock, quarried near the plant. This company was particularly fortunate in its quarry site, as previous to their advent a former company had operated a commercial stone quarry on the property. This operation had removed not only the overlying clay and loam surface but also a layer of hard limestone, and as a result the wool rock was stripped and exposed over a large area. In this particular locality, moreover, the wool rock apparently attains its maximum thickness in the State. The face, as exposed in the quarry, has a vertical height of roughly 60 feet. Future plans are to operate the quarry with churn drills, carrying the face the full height of the deposit. At present, air hammer drills are used on shallow benches. The stone is blasted with 40 per cent dynamite and loaded by hand into small steel quarry cars, which are hauled up an incline and dumped on the charging floor above the two steel water-jacketed cupolas.

Cupolas are charged by hand with rock and coke, and the wool is blown by steam in the usual manner. The plans call for installing additional cupolas when the demand requires.

Considerable study is apparent in the design of the blowing room and in the subsequent processing of the wool. The blow room itself has vertical concrete side walls 6 feet apart, and the floor is a conveyor belt which, being inclined, also acts as an elevator and carries the blown wool the full length of the blow room to the top of the factory.

Ingenious devices in the process enable the wool to be controlled uniformly for thickness and density over the full width of the conveyor. As the wool comes from the blowing chamber in a continuous blanket of predetermined thickness and density it is discharged onto a descending conveyor where circular slitting knives divide it into widths convenient for different uses and for rolling up at the lower end into rolls. These can then be wrapped in paper by suitable machinery in a manner similar to the wrapping of cotton batting.

The wool is not as yet fabricated into any product other than the blanket form, although future plans call for such fabrication as markets may require.

The potential capacity of the plant is 4,000 pounds per hour.

DISCUSSION OF TECHNICAL PHASES

General

Mineral wool is manufactured by first fusing the necessary raw materials to a liquid slag and then blowing this molten slag into wool.

The resulting wool, whether made from blast furnace slag, natural rock, or a combination of raw materials, is essentially the same for all market purposes. Technically, this statement may be disputed for the reason that blast-furnace slags often contain small amounts of sulphur which if present in the sulphide form in wool, would have a tendency to corrode any metal such as reinforcing metal, oven-sheathing, water pipes, etc., with which the wool might come in contact. However, since rock wool also is likely to contain this element, (originally in the fuel) such wool might be objected to on the same grounds.

In any event, sulphur may be considered detrimental only when it is present in the sulphide form. If it be entirely oxidized to sulphate the detrimental action is greatly reduced if not entirely eliminated. In this connection it is interesting to note the results of experiments by various investigators as reported by the National Slag Association.[8] These experiments, as listed by the association, indicate that slag wool has no corrosive action on steel inclosed within it. On the other hand, manufacturers of rock wool claim this is the fundamental difference between rock and slag wools. In the writer's opinion this matter of sulphide and sulphate content is a pertinent subject for research by wool manufacturers, as it embraces the whole question of raw materials.

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8 - National Slag Association, Is There Any Corrosive Quality in Slag. Symposium No. 10, 937 Leader Bldg., Cleveland, Ohio, 1928.

Cupola Charge

The cupola charge varies greatly in different plants. As Fuel is one of the major constituents of the charge and probably the most expensive, pound for pound, its consumption is of great economic importance. In this connection it is interesting to note the great variation in fuel ratios as used in the plants visited. In order to avoid exposure of individual operations, ratios only are given, without key to plants.

Variations in Fuel Consumption at Different Plants

(Tons slag or rock melted per ton of fuel used)

Rock plants	Slag plants
3	3.5
1.3	2
5	1.9 1/
2.1	3.7
2.8 2/	2.8 2/

1 - Includes a small addition of coke.
2 - Unweighted average of four plants.

These rather wide variations in fuel efficiency obtained by different operators indicate the need for careful study of this problem.

One operator reports maximum and minimum limits for wool rock analyses to produce good wool as follows:

	SiO_2	Fe_2O_3 Al_2O_3	CaO	MgO	CO_2
Maximum . . .	34.22	11.54	15.80	10.98	21.90
Minimum . . .	28.28	10.00	23.10	8.68	18.14

Typical analyses of slags used in making mineral wool are as follows:

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	S
38.0	1.0	11.0	28.0	19.0	.5-.8
38.4	0.7	10.5	31.5	15.3	1.6

An analysis of rock wool as obtained some time ago was as follows:

SiO	Al_2O_3 Fe_2O_3	CaO	MgO	S	Undetermined
42.84	1.40	51.74	2.75	0.0	1.27

While slag, either by itself or mixed with limestone, and natural wool rock are the two principal raw materials used, at least one manufacturer produces wool from silica rock and calcite. By proper chemical control, wool can be made from a number of materials.

Temperature Control

The fusion temperature obtained in the cupolas is reported as ranging from 2,800 to 3,000°F. There are no data as to whether the temperature or the time required for fusion varies with different raw materials. One operator, however, reports that wool rock obtained on the surface of the quarry is easier to fuse than that at some distance below the surface. At this quarry the surface rock presented a yellowish color while that below was blue, indicating that changes due to alteration by descending surface waters may have a bearing on fusibility.

Blowing Wool

Irrespective of the temperature at which the materials fuse, the temperature or at least the fluidity of the issuing stream of slag is of the utmost importance. The quality of the resulting wool with regard to amount of shot contained and length and flexibility of threads, depends on the temperature of the slag stream when it encounters the high-pressure steam. Careful research into several phases of this step in the operation will undoubtedly prove fruitful. Mention may be made of the following:

1. The relation between the slag temperature and the length of fiber.

2. The relation between the size of the slag stream and the quality of the wool.

3. The relation between the temperature of the slag and the temperature and pressure of the steam.

4. The relation between the quality of the wool and the air currents set up in the wool room by the blowing operation.

One plant visited several years ago by the author used compressed air instead of steam in blowing a slag wool. The wool produced exhibited extremely long fibers, but it is not known whether this was due to the use of air instead of steam or to the composition or temperature of the slag stream.

Collection of Blown Wool

Recent progress in the industry indicates a decided trend toward mechanical and automatic handling of the product and a decrease in manual labor. This result is in line with the mechanical progress of the times; however, while considerable progress has been made, there are many problems yet to be solved. It is interesting to note the various ways in which different operators are using automatic conveyors to eliminate hand collection.

Production and Productive Capacity

Available production statistics are summarized in Mineral Industry for 1911 as follows:

Production of Mineral Wool in the United States

(In tons of 2,000 pounds)

Year	Amount	Value	Per ton	Year	Amount	Value	Per ton
1900	6,002	$60,320	$10.05	1906	5,375	$55,550	$10.33
1901	6,272	68,992	11.00	1907	9,008	81,769	9.08
1902	10,843	105,814	9.67	1908	9,197	77,228	8.40
1903	(1)	- - -	- - -	1909	11,626	101,621	8.74
1904	(1)	- - -	- - -	1910	8,408	84,012	9.99
1905	6,164	69,560	11.28	1911	7,514	65,500	8.72

(1) - No statistics collected.

Although no actural figures for mineral-wool production appear to have been collected, the industry seems to have grown considerably since 1911. The 24 cupolas listed in the eight plants now operating have a potential capacity of 24,000 pounds of wool per hour. On the basis of a 200-day year, and allowing 24 hours per day for 22 cupolas and 16 hours daily for the two brick cupolas, the total annual production capacity can be calculated at roughly 54,400 tons. While this estimate is doubtless excessive, the output is evidently several times greater now than in 1911.

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